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research trends

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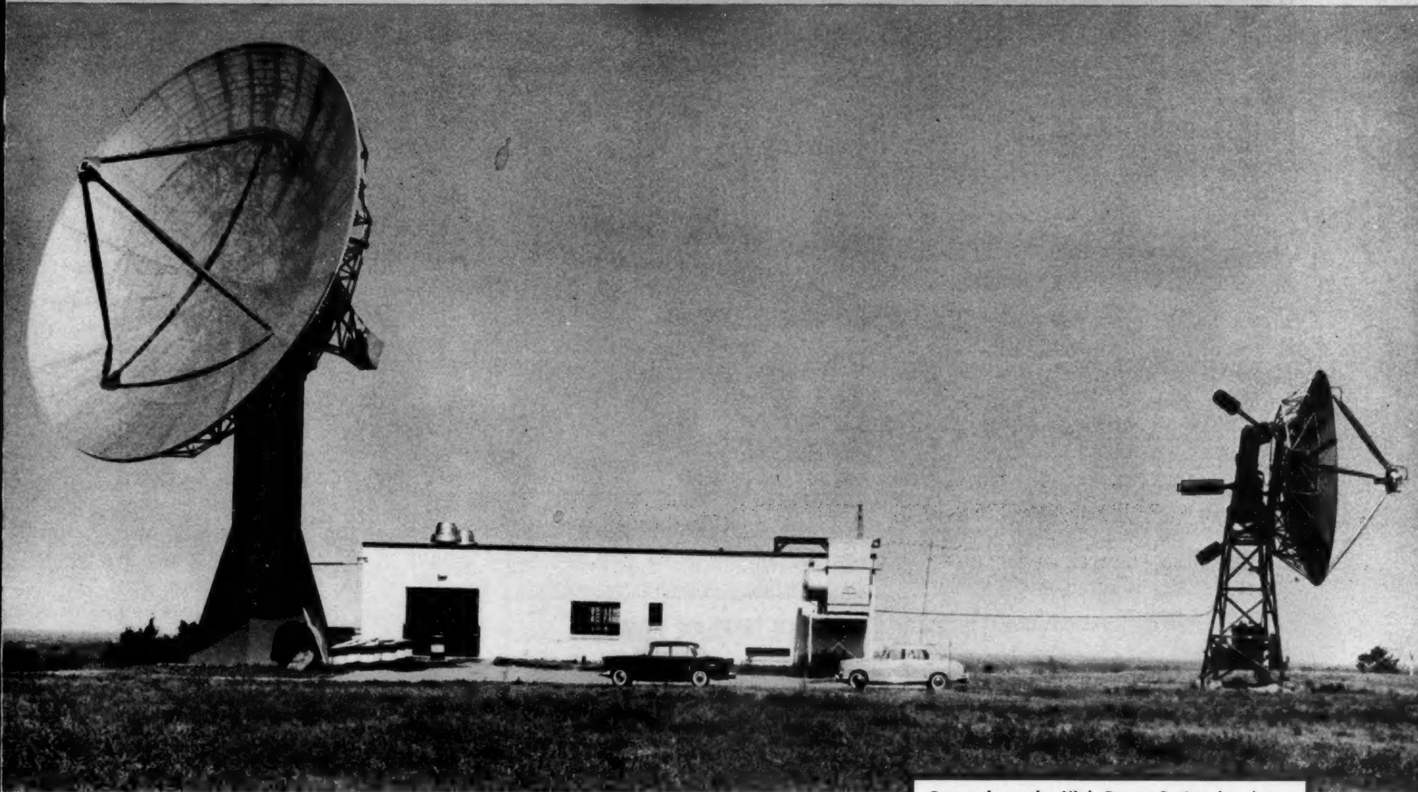


Research on the High Power Project has been conducted by Cornell Aeronautical Laboratory for the Defense Department's Advanced Research Projects Agency under the supervision of the Army Rocket and Guided Missile Agency.

High Power Microwave Radar Research...

by RICHARD C. BEITZ

IN order to detect satellites and incoming ICBM's, far more powerful radars than those now operational will have to be used. This is the most pressing need for high power microwave* radar.

Radars designed to "see" and track ballistic missiles, particularly those of five to ten years hence, will need to be different from radars designed to see such large targets as aircraft. The reduced size of such targets, and the long ranges at which they must be intercepted, will require extremely powerful transmitters and very sensitive receiving equipment. Under conditions of sufficient power and high receiver sensitivity, the limiting noise for a space radar will be the energy backscattered from the region in which the target is located — in the case of anti-missile radars, the charged particles of the ionosphere.

With these considerations in mind, much microwave radar research at Cornell Aeronautical Laboratory over the past several years, has been directed at experimental investigations of the production and radiation of high peak power at wavelengths in the ten centimeter region. The Laboratory has demonstrated the feasibility of radiating much higher peak pulse power in the microwave spectrum than had previously been thought possible. But these techniques have by no means been pushed to their practical limits. From the radar engineering point of view, the one design parameter which had appeared to be limiting has, in principle, been greatly extended, and allows the radar system designer

*Wavelengths less than 30 centimeters.

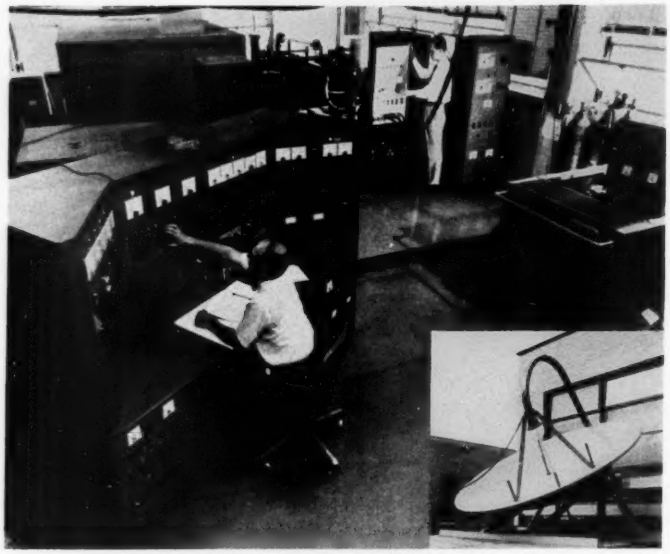


FIG. 1 — 21 Megawatt Transmitter.

far more freedom than had been the case previously. A decade ago, "powerful" microwave radars emitted peak power of only 250 kilowatts. Today, microwave radars with ten times this capability, or 2.5 megawatts, are considered "powerful". This level is not far below the point at which conventional microwave transmission lines and primary feed systems break down electrically. The research radar now used for the High Power Project is rated at 50 megawatts peak power.

WHAT IS PEAK POWER?

"Peak" power is the power radiated for the duration of the pulse. "Average" power is the power radiated through an entire operating cycle that is integrated through the time interval from the beginning of one pulse to the beginning of the next.

21 Megawatts Emitted

Over two years ago, a 21-megawatt peak power radar beam was experimentally emitted into space from Cornell Aeronautical Laboratory. This breakthrough came as the result of considerable fundamental study in the use of special transmission line and feed techniques which permit conduction and radiation of very high microwave power. Figure 1 is one of the transmitters in use for that series of experiments, with an inset of the antenna and feed. The transmitter (Figure 1) operated on a wavelength of 10 centimeters, and furnished 60 pulses of two microseconds duration per second, with a peak pulse power of 21 million watts.

Ordinary waveguide transmission systems at this wavelength break down at power levels of two to three million watts. These extremely high peak power levels were transmitted through highly evacuated waveguide and emitted from a special gaseous-dielectric lens, serving as a primary feed which illuminated a conventional parabolic antenna. The first High Power radar test set was capable of relatively low average power — about three to five kilowatts.

Since then, a new research radar (cover picture) has been placed in operation. The transmitter is capable of 50 kilowatts average power, with a peak pulse power of 50 million watts. It is used in connection with highly sensitive receiving equipment, including various solid-state amplifying devices.

A new location for the High Power Project has been developed some ten miles northeast of Cornell Aeronautical Laboratory. Problems of radio frequency interference, high industrial electrical noise levels, and geometric factors, such as horizon visibility, required employment of a site remote from the main Laboratory.

The antenna is a paraboloid 60 feet in diameter, mounted so that it may be pointed rapidly in any horizontal or vertical direction. The skin or antenna surface matches the surface of a perfect paraboloid within about ⅛", and consequently may be used throughout the microwave spectrum. The antenna surface is formed of aluminum plates perforated with ¼" holes so that half the skin area is open. This skin treatment reduces wind load and the accumulation of water and snow. The primary feed is supported at the focal point of the antenna by means of three fibreglass spars.

At the operating wavelength, the antenna emits a conical beam with an apex angle of 1/3°. The antenna may be pointed in any desired direction with a precision of one minute of arc and may be driven in any direction at an angular rate of 10° per second. It is mounted with its center at the top of a 50-foot tower, so that when the antenna is pointed at the horizon, its uppermost rim reaches a height of 80 feet. The tower is rigidly bolted to a concrete slab 20 x 20 feet, six feet in thickness which rests upon bedrock. The entire assembly (foundation, tower, and paraboloid) weighs 350 tons.

New Techniques Sought

Research in progress has several goals intended to point the way for the exploitation of new techniques. Much of the work is aimed at the determination of the peak and average power limitations of radar transmission lines, feed-antenna systems utilizing microwave lens techniques, high power "duplexing",* and the combination of extremely sensitive receivers with powerful transmitters and high gain antennas.

The influence of possible radio propagation effects which might result from the emission of very high microwave power is also under investigation. These effects have been called a "secondary noise level", larger than the normal input circuit noise of a very sensitive radar receiver, which might be set up as a result of transmitted energy backscattered from the ionosphere or from other discontinuities intercepted by the radar beam. Before attempting to apply very high peak power to operational radar systems, it is most important to know whether some power level exists at which the total system noise level might limit additional increases. In this case, noise from backscatter would increase as a function of the power so that no improvement could

*Using one antenna for transmitting and receiving.

be realized in signal-to-noise ratio through further increase in peak power.

Purpose of the Project

Thus, problems studied on CAL's High Power Project are twofold: finding the means of radiating very high peak microwave radar power, and experimentally defining the limiting noise level involved in the use of high power microwave radar.

Limitations on the power levels which may be transmitted and radiated are imposed by the physical dimensions of the components for the microwave region. At the power levels involved, peak voltages appearing across transmission line components, as well as at the antenna feed or primary radiator, are sufficiently high to cause arc-over or electrical discharge. Constructing equipment for multimegawatt microwave powers is more a problem of handling and radiating the energy than of generating it.

The transmission line employed in CAL's first High Power transmitter consisted of standard S-band waveguide, evacuated to a pressure of 10^{-7} mm of mercury. This type of waveguide, when filled with air at atmospheric pressure, breaks down and arcs over at a power level of 2 to 3 megawatts. The breakdown is caused by ionization of the air within the guide. By evacuating to such a pressure that the mean free path of the remaining molecules is sufficiently large compared to the waveguide's dimensions, it may carry far higher power without breakdown. Experiments with the evacuated transmission line demonstrates not only its capability of withstanding high peak power, but also its efficiency in handling high average power.

WHAT IS A RADAR PULSE?
A pulse is a short burst of radio frequency energy radiated intermittently.

Breakdown Caused by Ionization

In a waveguide containing air or other readily ionizable gases, each small pit, tool mark, or other imperfection in the waveguide wall is a possible source of localized field concentrations which encourage the formation of ion clouds. Each local field concentration may give rise to a corona discharge which, in itself, dissipates only a small amount of energy. The integrated effects of these discontinuities appear as an increase in the radio frequency power loss per linear foot of waveguide. In addition, higher temperatures result when this power loss is converted into heat in the waveguide walls. High vacuum systems eliminate this type of power loss by removing the source of the ions. In the 50-megawatt transmitter, the output waveguide transmission line is pressurized with a dielectric gas which withstands a much higher potential than air. The pressure within the guide is raised to three atmospheres absolute, which is sufficient to permit operation of the transmission line at power levels of about 70 megawatts.

The chief advantage of evacuated high power transmission systems is that most of the ionizable material has been removed, so that concentration of the electric field may be greater than otherwise without giving rise to arcs or corona discharges. The greatest disadvantage of such systems is the inherent difficulty of fabricating and maintaining them. The advantage in the use of pressurized dielectric gas is the simplicity with which the radio frequency plumbing system can be constructed, and the comparatively simple maintenance required. Somewhat greater care must be taken to prevent localized field concentrations in pressurized systems than in evacuated transmission lines.

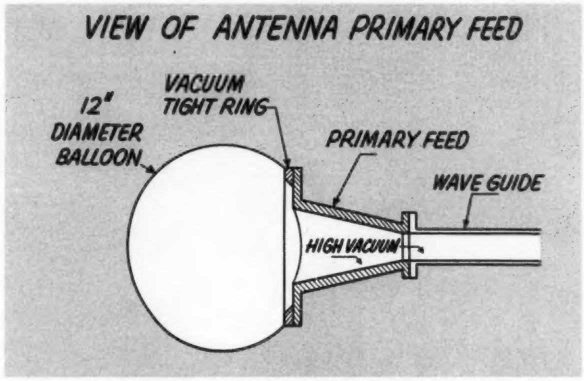


FIG. 2 — **Feed Unit for 21-Megawatt Transmitter. It operates with the inner section either evacuated or pressurized with dielectric gas; the outer section between the Mylar window and the plastic balloon is filled with a dielectric gas slightly above atmospheric pressure. At the point where energy emerges through the Mylar window, the dimensions of the horn feed unit are such that ionization and resulting breakdown would occur at eight megawatts.**

At some point, if energy is to be radiated, the microwave energy must leave the transmission line and enter the atmosphere. The primary feed unit shown in Figure 2 was used on the 21-megawatt transmitter and a modification of it has been installed on the new 50-megawatt transmitter. Addition of the balloon permits the radiation pattern to expand so that at the point of emergence of the energy through the balloon wall into the air, the peripheral discharge path along the outer wall of the balloon is about three feet long. This is sufficient to "hold off" discharge to power levels considerably greater than 50 megawatts.

Conventional Duplexers not Suitable

For purposes of high power microwave work, the rotating joints and duplexers used in microwave practice are not suitable. Rotating joints must be capable of supporting the internal atmospheres needed in high power transmission systems, and must be designed so that no mode-suppressing* parts or other metallic components normally held in place by solid dielectric materials are required. The reason for this is that there are no solid dielectric materials capable of withstanding the radio frequency potentials present at multimegawatt levels across such waveguide transmission lines. The problem of duplexing is complicated by the very high power levels which must be prevented from entering the extremely sensitive receiver. The parametric amplifier used in the receiver input circuit is subject to overload at much lower levels than more conven-

*A device designed to pass energy along a waveguide in a particular field pattern.

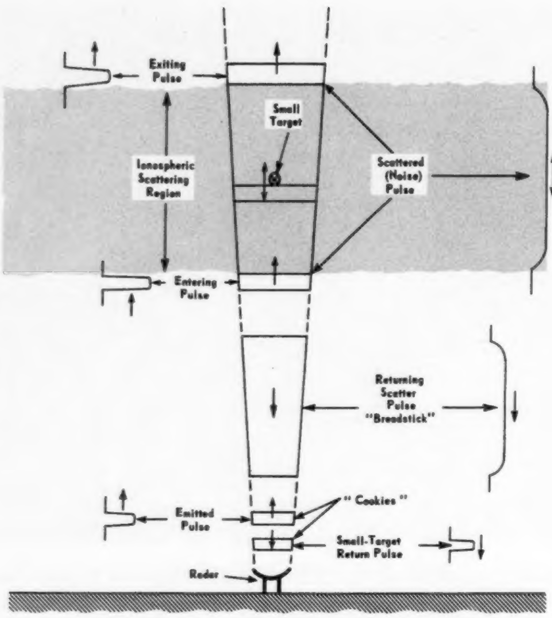


FIG. 3 — **Ionospheric Backscatter Diagram.**

tional radar receiver input circuits, while the transmitter peak power level is much higher than in conventional microwave radars.

The duplexer installed in the 50-megawatt equipment is an ATR (anti-transmit-receive) device. It was chosen primarily because its construction permits employment of simple and effective cooling methods. Power losses in transmission line components show up in two ways where both high peak and average power must be handled: in the heating of components due to ohmic losses, and in reflected losses introduced by corona discharges which result in impedance discontinuities. Design of all transmission line components, including the waveguide transmission line itself, must allow for these considerations. Therefore, great care was exercised to avoid electric field concentrations and to provide for adequate cooling of all current-carrying metallic parts.

Earth Thermal Noise a Problem

Because of its temperature, the earth radiates radio frequency energy. An antenna system for purposes of the High Power Project should respond ideally only to energy arriving from the direction in which it is pointed. All practical antenna systems, however, receive energy from other directions. Energy entering the primary feed from behind the antenna, when the antenna is pointed upwards, adds to the noise of the system. Careful design of the primary feed pattern was necessary to keep earth thermal noise from entering the antenna backlobe.

Energy diffracted at the edge of the antenna and reaching the feed must arrive at the edge of the dish through a very narrow range of incident angles so that it originates from a rather small area behind or beneath the antenna. The earth's thermal energy included in the part of the feed pattern which overlaps the edge of the antenna originates from a substantial "doughnut-shaped" sector of the earth's surface, since the feed has some response approaching 90° to its axis.

The pulse length of the new transmitter* is adjustable from one to 16 microseconds, with a pulse repetition rate between 50 and 250 pulses per second. Its operating wavelength is approximately 10 centimeters. A crystal controlled oscillator maintains frequency of the transmitter within three kilocycles. The same crystal control system stabilizes the receiver frequency, so that both transmitter and receiver tend to "drift" together, thus providing much better transmit-receive frequency stability than three kilocycles. This type of frequency stability is desirable to permit studies of Doppler phenomena.

The receiver utilizes a parametric amplifier input circuit, and an intermediate frequency and video amplifier system incorporating adjustable bandwidth to permit measurements of radio propagation factors to be studied in the High Power program.

Cookies and Breadsticks

In any practical microwave system, both thermal and bandwidth-dependent circuit noise will be present in addition to the energy backscattered. Conceptually, there must be an optimum power level below which a poorer signal-to-noise ratio would result. Figure 3 shows "cookie-shaped" pulses emitted by a radar. A "cookie" may be defined for our purposes as the volume of space included within the antenna pattern having a thickness equal to the distance traversed by electromagnetic energy in the duration of one pulse. When these short pulses enter a region of scattering particles, energy is reflected, some of it back toward the radar. This continues until the short pulse emerges from such a region, and a long backscattered pulse (the "breadstick") returning toward the radar is the result. If a small target located in the backscattering region is intercepted by a rising short pulse, a returning short pulse having approximately the same dimensions as that emitted will result. This target pulse will return to the radar during the interval when the long backscatter pulse is being received.

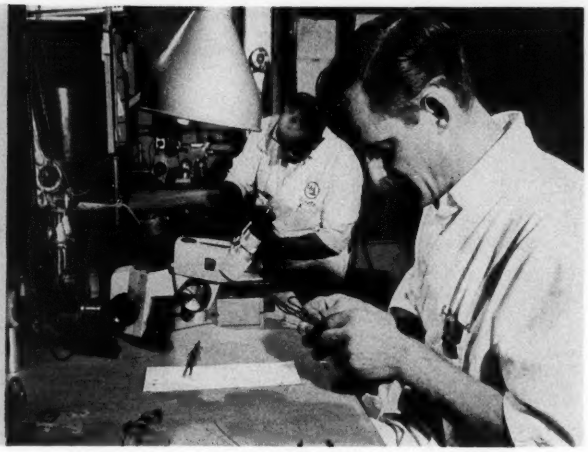
To discriminate in favor of the target return, the frequency bandwidth of the receiver must be sufficient to resolve a pulse having dimensions equivalent to that originally emitted by the transmitter. If we wish to discriminate in favor of the much longer ionospheric pulse, however, the optimum bandwidth for the receiver will be much narrower. To study the phenomena associated with high power microwave backscatter, therefore, the receiving equipment must be extremely sensitive and must have a frequency response adjustable over a very wide range.

When the High Peak Power microwave radar research program was begun, many experts believed radar incapable of detecting and tracking ballistic missiles. Achievement of present goals for the program should aid in the solution of many problems now restricting the effective employment of radar for this mission, and should result in providing data for the design and construction of operational defense radars.

*This transmitter was designed and built by FXR, Inc. to meet performance specifications set forth by CAL.

The Eyes and Ears of a Shock Tunnel

by ROBERT C. MacARTHUR



Not the least spectacular of space age successes have been in the fields of instrumentation and miniaturization.

The attempt to simulate in the laboratory conditions encountered by a vehicle as it leaves or re-enters the atmosphere, has made necessary the development of instruments remarkable for their minuteness and sensitivity.

To create hypersonic speeds and near-solar surface temperatures in a shock tunnel at reasonable cost, facilities must be reduced to a moderate size. Thus, models representing orbital vehicles are much smaller than actual vehicles. Their shapes and configurations, of course, are carefully scaled.

Because the maximum useful test period in a hypersonic shock tunnel* is seldom over 10 milliseconds, instruments able to record time histories of such parameters as pressure, force, flow patterns, heat transfer rate and gas composition, had to be purchased, adapted or developed.

Today, technicians in Cornell Aeronautical Laboratory's Applied Hypersonic Research Department, are engaged in constructing and installing instruments, many with parts of microscopic size, designed for recording in milliseconds, the parameters mentioned above.

WHAT IS A SHOCK TUNNEL?

The principal components of a shock tunnel are a shock tube, a nozzle, a test section and a receiving tank. The shock tube itself consists of a high-pressure tank (called the driver), and a long, smooth pipe known as the driven tube. Between these two sections, the driver and the driven section, is a diaphragm capable of withstanding the pressure in the driver section, yet which may be ruptured at will. A gas contained in the high-pressure section actually drives the air in the driven tube. Driver gases are selected for their low molecular weight and their high energy-to-mass ratio. Although hydrogen best fulfills these specifications, it is dangerous to handle because of its explosive properties when air is present. Air is used in the driven tube and becomes the test gas.[1]

Tunnel Must Be Calibrated

Before a model is placed in the test section of CAL's 24″ shock tunnel, testing engineers must know the temperature and pressure of the driver gas, the speed of the shock wave, and the static and dynamic pressures in the test section. Taking these measurements prior to a test run is called "calibrating" the tunnel.

Transducers Developed

To make these measurements, pressure transducers capable of accurately measuring pressures from .006 of a psi to 6000 psi were required. The higher range is the pressure of the driver gas before the diaphragm bursts. For this purpose it was possible to purchase a satisfactory gage. To measure the smaller pressures, more sensitive transducers were necessary. These had to be developed at CAL. The pressure at the end of the shock tube before the shock wave enters the nozzle is a transient and lasts only a few thousandths of a second, but is also of interest to the test. Fortunately, the internal combustion engine and fuel industries have for many years provided histories of the pressure in the combustion chamber of engines with transducers employing the piezoelectric properties of a quartz crystal. So this transducer, too, was commercially available.

As the heated and highly compressed air at the end of the shock tube passes through the nozzle in the throat of the driven section of the tunnel, it expands, cools, and assumes a lower static pressure. This pressure, (experienced by a body traveling with the flow) will change by a factor of one one-millionth until it reaches Mach No. 16, or 16 times the speed of sound.

This pressure of about .006 of a pound per square inch or 1/2500 of the air pressure around us, must be measured in the time it takes an auto traveling at 60 miles per hour to move three inches, or the sound of one's voice to travel three feet—about three thousandths of a second.

Lead zirconium titanate possesses the remarkable capability of creating a voltage when subjected to bending

*The Wave Superheater Hypersonic Tunnel now under construction at CAL for the Air Force is expected to provide a test period of 15 seconds.

[1]See "New Tool for Research", Martin, James E., Research Trends, Vol. VII, No. 4, Winter, 1960.

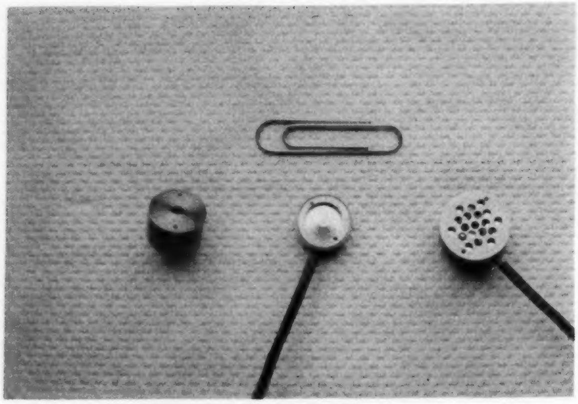


FIG. 1 — **Pressure Transducers.**

forces. Thus it was possible to construct very small pressure transducers (Fig. 1) employing the piezoelectric qualities of this material. By using suitable amplifiers and an oscilloscope, these very small pressures can be recorded though the allotted time is only 3 milliseconds.

These transducers, in addition to being sensitive to pressure, had to meet specifications of minuteness, freedom from radiant energy and acceleration effects. They also had to withstand a pressure of 30 pounds per square inch. This is the pressure at the end of the test run when the driven gas expands into the dump tank. The most sensitive of these transducers (shown on the left in Fig. 1) produces 7.5 volts per psi and has a noise level equivalent to about ten one-millionths of a psi. This is a ratio of allowable pressure to smallest pressure measurable in three milliseconds of about three million to one. The linear range of the transducer is about one psi.

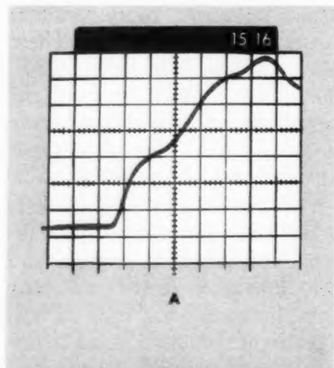


FIG. 2 — **Balance Records.**

The transducer in the center of Figure 1 is smaller but less sensitive than the one on the left. It measures $\frac{1}{2}$ inch in diameter, is $\frac{1}{8}$th of an inch thick, and is easier to construct than the others. It may be installed in most models directly under the pressure orifice and even in thin model wings. The transducer on the right is less sensitive than the others, is capable of measuring 15 psi and has a noise level of the equivalent of about .0005 psi.

Any of the three transducers in Figure 1 may be used in calibrating the tunnel or they may be mounted in a model undergoing test. As many as 30 pressures may be recorded at one time on 15 dual-channel oscilloscopes in the control room of the Laboratory's 24″ tunnel.

Force and Heat Transfer Rate

Force measurements and heat transfer rate are data frequently demanded by sponsors of hypersonic tests.

Model forces may be considered to be the summation of all the local pressures on their associated areas and could be obtained from pressure measurements if space permitted. There is, however, a practical limit to the number of transducers that may be mounted in a model if we consider lead wires and recording systems.

Forces are currently measured at CAL by a combination balance system of accelerometers and small

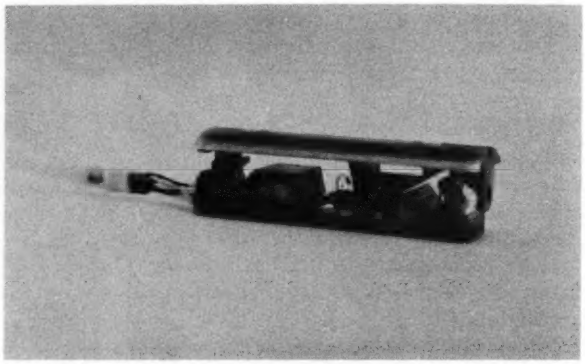


FIG. 3 — **Strain-Gage Balance.**

steel beams with resistance wire or foil strain gages cemented to them. This combination is referred to at the Laboratory as a "compensated" balance. The wire strain gages experience aerodynamic and inertial loads; the accelerometers measure only inertial loads. Because the aerodynamic force is the only data desired, the accelerometer signals are subtracted from the strain gage signals. The difference is the aerodynamic forces.

This combination is not affected by sting or balance compliance. It is affected, however, as is each individual system, by model compliance. Thus, the model should be as stiff and light as possible to give it a high natural frequency. Figure 2 shows a typical record from a suddenly released load of (a) the strain gage output, (b) the accelerometer output and (c) the combined signal. Note the presence of sting oscillation in (a) and (b) but not in (c). It is easy to see that a measure of the true load (height of record) would be difficult if not impossible to obtain from (a) or (b) but is readily obtained from (c). Figure 3 shows a typical three-component strain-gage type balance, and Figure 4 a "crystal" balance. The latter uses piezoelectric materials for force measurement.

Heat transfer rate is the rate at which heat from the heated air passes into various parts of the model, a parameter of great interest in the design of re-entry

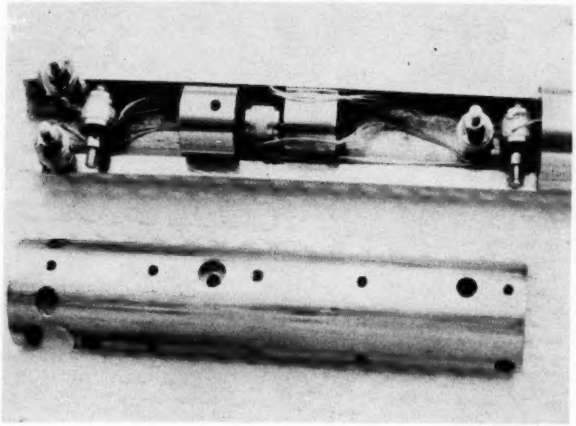


FIG. 4 — **Crystal Balance.**

vehicles. Heat transfer rate is, however, difficult to calculate because of the high velocities and boundary conditions. To measure heat transfer rate, very thin films of platinum are deposited on glass buttons and baked to provide an intimate bond to the glass. These films are about 1/4 inch long, 1/20th of an inch wide and about one millionth of an inch thick. These films are treated as resistance thermometer elements and used to provide a time record of the temperature of the glass surface. When high temperature air passes over the glass buttons imbedded in the model surface, part of the thermal energy is absorbed by each layer of glass—some at surface layers, some at deeper layers. Because of this phenomenon, the absorption and transmission of thermal energy, the surface temperature varies as the square root of time when a steady flow is suddenly initiated. Passive circuit components, resistors and capacitors, have also been incorporated to provide for an inverse electrical operation on the signal to obtain direct records of heat transfer rate. Enough instrumentation is employed to record 30 channels of heat transfer rates at various locations on the model.

Dynamic Stability Tests

The reader may be surprised to learn that dynamic stability tests are possible in a shock tunnel despite the limited test time.

To perform these tests, extremely low density models limited thus far to bodies of revolution, (cylinders, cones, etc., which provide a maximum of stiffness) are mounted one at a time on steel beams instrumented with calibrated resistance-wire strain gages. By deflecting the model to a small incremental angle of attack, energy is stored in the beams. The model is held at this deflection by a catch until the air flow begins. The catch is released by either an electromagnet or by the air acting upon a vane. By using an electromagnet with timing circuits, the model can be freed to oscillate at a precisely chosen time. The model must be light and the beam stiff in order to obtain a natural oscillating frequency of several hundred cycles per second. This will assure several cycles of oscillation during the test period. Prior to employing this technique, beams must be statically calibrated and oscillations must be recorded in still air or in a vacuum to note the amount of mechanical damping in the system. Mechanical damping is treated as a tare when determining the damping due to aerodynamic effects. Extreme care must be exercised to avoid spurious disturbances that might also be recorded at the time the shock wave is released.

The quest for more knowledge of what happens to a vehicle traveling at hypersonic speeds creates a continuing need for instruments to provide this information. As this is being written, instruments are under development at Cornell Aeronautical Laboratory to measure several additional parameters such as the degree of molecular dissociation and recombination rates as the dissociated gases recombine.

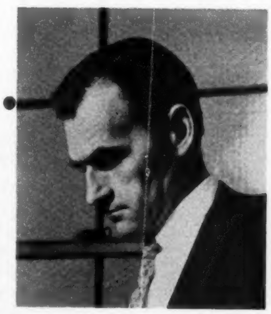
ABOUT THE AUTHORS

RICHARD C. BEITZ, author of "High Power Microwave Research" was project engineer for the High Power Project when the section (team) successfully emitted 21 million watts of power. He is currently head of the Laboratory's Microwave Techniques Section of the Applied Physics Department.

Mr. Beitz's special interests and background are in the fields of optical and electro-optical instrumentation; precision electromechancial devices; electromagnet and photoelectric problems; photoconductivity and microwave optics, and radar astronomy.

Before joining Cornell Aeronautical Laboratory in 1954, he spent 15 years as a research physicist with the American Optical Company.

Mr. Beitz holds a B.A. degree in physics from Colgate University, is a member of the Optical Society of America, American Physical Society and Sigma Xi.



ROBERT C. MacARTHUR, author of "The Eyes and Ears of a Shock Tunnel," has been associated with wind tunnel instrumentation at C. A. L. for the past 12 years and is responsible for much of the instrumentation in use in the Laboratory's transonic wind tunnel. In recent years his efforts have been applied to instrumentation of hypersonic shock tunnels and he is now responsible for the research and development of instrumentation connected with these facilities.

With the outbreak of World War II, Mr. MacArthur left the University of Buffalo Medical School where he was engaged in biochemical research to become chief inspector of military optics for the American Optical Company, Scientific Division. He also worked as project engineer for the Bendix Radio Division of Bendix Aviation.

His undergraduate work in science was done at Syracuse University, Oberlin College and the University of Michigan.

RECENT CAL PUBLICATIONS

The Laboratory invites requests for its unclassified publications as a public service. Supplies of some publications are limited, and those marked with an asterisk may be distributed only within the United States. Please direct your request to the Editor, Research Trends, Cornell Aeronautical Laboratory, Buffalo 21, New York.

"THE THERMAL DESIGN OF HIGH TEMPERATURE ELECTRONIC PARTS AND EQUIPMENTS," Coleman, John B. and Welsh, James P.; CAL Report No. HF-1053-D-13; April 1959; 116 pages.*

This report delineates the findings of a program sponsored by the Department of the Navy, Bureau of Ships, to survey and study the problem of heat transfer in electronic equipment operating in high-temperature (160 to 350°C) environments. Various approaches to the thermal design of high-temperature parts and equipment are described.

"A METHOD FOR HEAT REJECTION FROM SPACE POWER-PLANTS," Weatherston, Roger C. and Smith, William C.; Reprinted from ARS Journal, March 1960; 2 pages.

Fundamental to the design of closed-cycle power plants providing high specific impulse for space propulsion motors is the means by which waste heat is dissipated. Heat can be rejected to a space environment only by radiation. The conventional radiator for high power levels is very massive; above the megawatt power level, in fact, its weight is about half of the weight of the power plant. A different type of radiator, described here, should weigh considerably less than conventional radiators.

"ON PREDICTING PERCEPTRON PERFORMANCE," Joseph, Roger D.; Paper presented at IRE National Convention, New York City; March 1960; 11 pages.

Perceptrons are devices intended to simulate a portion of the logic of the brain concerned with memory and recognition. Mathematical analyses of the three main types of elementary perceptrons are presented. The capabilities of these systems to classify certain environments are also given.

"IMPROVEMENT OF FERRYING RANGE OF ARMY HELICOPTERS," Final Report, Adler, Abraham C., Holm, Helen S. and Harrington, Shelby A.; CAL Report No. BB-1187-H-2; July 1959; 102 pages.*

A general study to determine the maximum attainable ferrying range of helicopters has been completed. For pure helicopters with no modifications other than fuel system auxiliaries, the ferrying range is approximately 1000 nautical miles with 10% reserve fuel.

"HYPERSONIC NOZZLE DESIGN TO AVOID PARTICLE DAMAGE," Wittliff, Charles, E.; Paper presented at Eleventh Supersonic Tunnel Association Meeting, Los Angeles, Calif., April 21, 1959; San Diego, Calif., April 22-23, 1959; 16 pages.

Although shock tunnels and other short duration wind tunnels may be plagued by small diaphragm particles in the air stream, there are nozzle design schemes that will prevent all or most of these particles from entering the test section. In general, these schemes require the use of a two-stage expansion nozzle and, consequently, are restricted to high Mach number designs. Several methods that will alleviate this problem while still providing an isentropic expansion process have been described and their pertinent features mentioned.

"HIGH-, LOW- AND BAND-PASS FILTERS FOR AUDIO AND SUB-AUDIO FREQUENCIES," Fryer, W. D.; Reprinted from Electronics, Vol. 32, No. 15; May 7, 1958; 23 pages.

A single triode plus three resistors and two capacitors comprise a network that may be either high- or low-pass filter having 12-db/octave attenuation. Filters can be cascaded for high-, low- or band-pass filters with slope any desired multiple of 12-db/octave with insertion loss of less than 2 db. Once designed, the filter can be changed to a new frequency by simple scale changes.

"DEVELOPMENT AND WIND TUNNEL TEST OF AN ALL-WEATHER VORTEX FREE-AIR THERMOMETER," Rosenthal, Paul; CAL Report No. IH-1228-P-1; May 15, 1959; 55 pages.

This report describes the design, fabrication and testing of three experimental models of the All-Weather Vortex Free-Air Thermometer. It also analyzes heat required to protect the thermometer against ice formation and discusses its performance in the icing wind tunnel.

"THE DEVELOPMENT AND FLIGHT EVALUATION OF A MECHANICALLY IMPLEMENTED NORMAL ACCELERATION LIMITING SYSTEM," Deazley, William R.; CAL Report No. TB-1158-F-1; November 1958; 85 pages.

This report describes the theory, design and flight test results of a non-electronic normal acceleration-limiting device. Flight tests indicate that the system provides acceleration limiting in a very effective manner no matter how hard the pilot attempts to exceed the limit. A discussion of further possible refinements to the system is included in the body of the report.

"A PERTURBATION TECHNIQUE FOR ANALOG COMPUTERS," Bush, L. and Orlando, P.; Reprinted from Institute of Radio Engineers Transactions on Electronic Computers, Vol. EC-8, No. 2; June 1959; 4 pages.

A study of the motion of a fin-stabilized rocket was undertaken to determine the effect of perturbing forces on the trajectory. The mechanization of a complete problem for an analog computer to include small disturbing forces would result in trajectories which are essentially indistinguishable from the "nominal" or "unperturbed" case because of analog computer accuracy limitations. Instead, the equations of motion for the "nominal" case and the "perturbed" case, derived by first order ballistic perturbation theory, were solved simultaneously with the nominal solution providing inputs to the perturbed solution. The analog computer solution provided both the nominal trajectory and perturbations from this trajectory.

"BOUNDARY-LAYER DISPLACEMENT AND LEADING-EDGE BLUNTNESS EFFECTS IN HIGH TEMPERATURE HYPERSONIC FLOW," Cheng, Hsien K., Hall, J. Gordon, Golian, Thaddeus C. and Hertzberg, Abraham; Revised I. A. S. Paper No. 60-38; CAL Report No. AD-1052-A-9; August 1960; 79 pages.

Two important features of hypersonic flow over slender or thin bodies are the displacement effect of the boundary layer and large downstream influence of leading-edge bluntness. The present paper contributes new theoretical and experimental results on this problem.

"PROPERTIES OF ASBESTOS REINFORCED LAMINATES AT ELEVATED TEMPERATURES," Wahl, Normal E.; S. A. E. Reprint No. 106V; October 5-9, 1959; 7 pages.

The need for low density, easily fabricated heat-resistant materials for rocket and missile construction has resulted in a continuing search for more effective combinations of known materials, as well as the development of new materials. The purpose of presenting this paper is to bring to the attention of design engineers some interesting results obtained in studies of composite materials that might be used for rocket or missile construction.